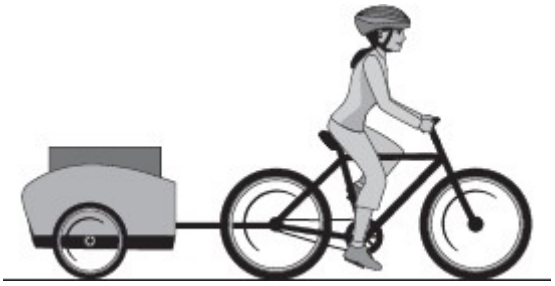
Connected Particles Exam Questions

Q1

A cyclist is towing a trailer behind her bicycle.

She is riding along a straight, horizontal path at a constant speed.



A tension of T newtons acts on the connecting rod between the bicycle and the trailer.

The cyclist is causing a constant driving force of 40 N to be applied whilst pedalling forwards on her bicycle.

The constant resistance force acting on the trailer is 12 N

(a) State the value of T giving a clear reason for your answer.

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(2)

(b) State one assumption you have made in reaching your answer to part (a).

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(1)

(c) Find the external resistance force acting on the cyclist and her bicycle.

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(2)

(Total 5 marks)

Q2

A tractor and its driver have a combined mass of m kilograms.

The tractor is towing a trailer of mass $4m$ kilograms in a straight line along a horizontal road.

The tractor and trailer are connected by a horizontal tow bar, modelled as a light rigid rod.

A driving force of 11 080 N and a total resistance force of 160 N act on the tractor.

A total resistance force of 600 N acts on the trailer.

The tractor and the trailer have an acceleration of 0.8 m s^{-2}

(a) Find m.

(3)

(b) Find the tension in the tow bar.

(2)

Extension

(c) At the instant the speed of the tractor reaches 18 km h^{-1} the tow bar breaks.

The total resistance force acting on the trailer remains constant.

Starting from the instant the tow bar breaks, calculate the time taken until the speed of the trailer reduces to 9 km h^{-1}

(4)

(Total 9 marks)

Mark schemes

Q1.

	Marking Instructions	AO	Marks	Typical Solution
(a)	Deduces $T = 12$	2.2a	B1	$T = 12$
	States clear reason For example: No resultant force since no acceleration T must balance the resistant force as speed is constant	2.4	E1	Constant speed means forces on trailer are in equilibrium
(b)	States one valid assumption For example: Rod is rigid Rod lies parallel to the direction of travel Rod is inextensible	3.5b	E1	The rod remains horizontal
(c)	Forms equilibrium equation of forces acting on cyclist and cycle PI by $R = 28$	3.3	M1	$40 = T + R$ $R = 28\,\text{N}$
	Obtains resistance force = 28 N Must state units	3.2a	A1	
				Total 5 marks

Q2.

	Marking Instructions	AO	Marks	Typical Solution
(a)	Models overall system as a single particle using Newton's second law, one side of equation correct. If two separate equations used, must eliminate T to obtain a single equation	AO3.3	M1	By $F = ma$ $11080 - 160 - 600 = 0.8(4m + m)$ $10320 = 4m$ $m = 2580$
	Obtains fully correct equation	AO1.1b	A1	
	Obtains correct value for m	AO1.1b	A1	

(b)	Models either tractor or trailer separately using resistance force, T and their m **value**. Tractor: $11080 - 160 - T = 0.8 \times m$	AO3.3	M1	Trailer: $T - 600 = 0.8 \times 4 \times 2580$ $T = 8856$ newtons
	Obtains correct value for T using their m value Condone omission of units.	AO1.1b	A1F	
(c)	Models trailer using only resistance force = ± 600 and *their* $4m$ value to find a from Newton's second law or finds s using energy.	AO3.4	M1	$-600 = 1032a$ $\Rightarrow a = -\frac{5}{86}$ m s^{-2}
	Finds the correct value of a or s (161.25)	AO1.1b	A1	18 km h^{-1} = 5 m s^{-1}
	Selects suitable suvat equation to find required time, using their calculated value for a or s and consistent units	AO3.4	M1	Using $v = u + at$: $2.5 = 5 + \left(-\frac{5}{86}\right)t$
	Obtains correct value for t **including units** CAO	AO1.1b	A1	Time taken, $t = 43$ seconds
				Total 9 marks